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SUPPLEMENT TO

VOYAGER THERMAL INSULATION SYSTEMS

PHASE II SUMMARY REPORT

LONG TERM VACUUM STORAGE TEST AND VIBRATION EFFECTS EVALUATION ON MULTI-LAYER SUPER INSULATION BLANKETS

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PREPARED FOR

JET PROPULSION LABORATORY
PASADENA, CALIFORNIA
UNDER JPL CONTRACT NO. 951537

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MISSILE AND SPACE DIVISION
Valley Forge Space Technology Center
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THIS WORK WAS PERFORMED FOR THE JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY, AS SPONSORED BY THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION UNDER CONTRACT NAS 7-100.

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This report was prepared by the General Electric Company under Contract No. 951537, Planetary Vehicle Thermal Insulation Systems, for the Jet Propulsion Laboratory. It is a supplement to the Phase II Summary Report, dated 11 September 1967. The work was administered under the technical direction of the Advanced Engineering Section, Engineering-Mechanics Division of the Jet Propulsion Laboratory, with Mr. Donald Ting acting as Technical Director.

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Approved by: Donald Ting

Donald Ting, Technical Director (PVTIS)
Jet Propulsion Laboratory

ABSTRACT

Super insulation blankets were subjected to a sixty day exposure to vacuum levels in the 10^{-8} torr range while radiating to walls cooled by liquid nitrogen. At the end of the sixty day time period, the blankets were subjected to broad-band vibration levels of 3.77 G to 4.66 G RMS while at vacuum/cryogenic conditions. There was no apparent physical damage to the insulation and no measurable change in the thermal performance.

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SECTION 1
INTRODUCTION

As part of the subject program, it was required to demonstrate that the super insulation material, when assembled into blankets, could survive the expected vibration levels caused by firing of the orbit insertion motor after several months of exposure to space vacuum and temperature conditions. A secondary objective was to measure the thermal performance of the insulation material after initial temperature stabilization and again after vibration to determine if any significant change in thermal performance occurred. For this test, the materials were exposed to vacuum levels in the 10^{-8} torr range and to a sink temperature below $-280^{\circ}F$. At the conclusion of the exposure period, and while the specimen was under vacuum/low temperature conditions, it was vibrated at the levels that approximate those shown in Figure 1-1 which are representative of vibration levels expected from a liquid rocket engine.

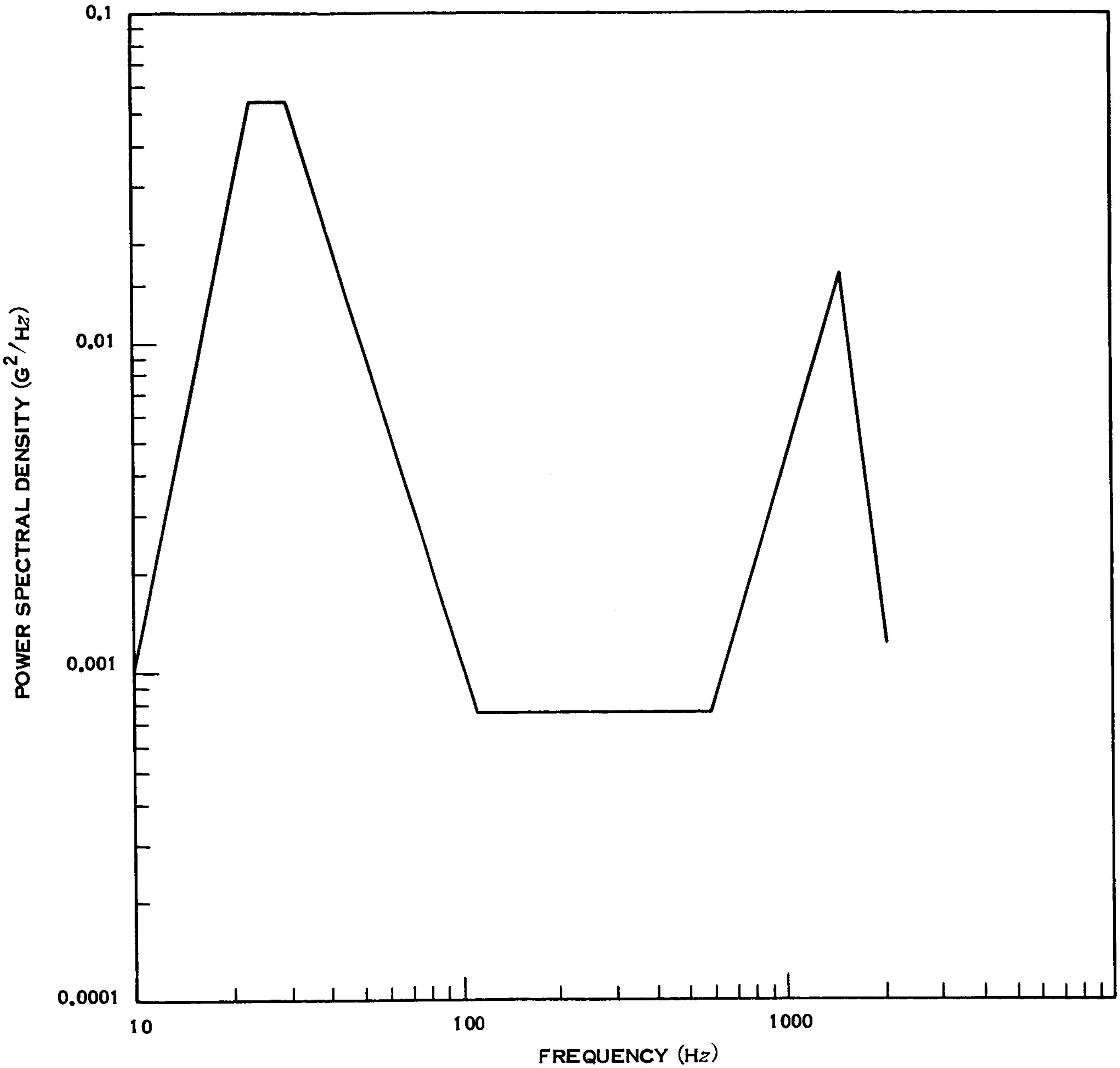


Figure 1-1. Random Vibration Spectrum

SECTION 2
TECHNICAL DISCUSSION

2.1 TEST FIXTURE DESCRIPTION

The test fixture was a 14-in. diameter by 14-in. long right circular cylinder as shown in Figures 2-1 and 2-2.

2.2 TEST BLANKET DESCRIPTION

The test blankets are as shown in Figures 2-3 through 2-7. The 1/4-mil gold coated Mylar and 1/2-mil gold coated Kapton were crinkled by pulling the sheet material through a Teflon die. The sheets were perforated prior to crinkling with nine 1/8-in. diameter holes per square foot. The uncoated 2 mil Kapton cover sheets were drilled with the same hole pattern. Holes to accommodate the Tinger fasteners were 0. 30 inches in diameter. The Tinger fasteners are described in Figure 2-8. The blankets were restrained on the posts by nylon split-washers snapped into the machined shoulder on top of the Tinger.

The blankets were taped at the joints with one inch wide, one mil Kapton tape coated with pressure sensitive cement.

The following materials and sources of supply were used.

1/4-mil, gold coated Mylar	National Metallizing
1/2-mil, gold coated Kapton	National Metallizing
2 mil Kapton cover	DuPont DeNemours, Inc.
Tinger Fasteners	General Electric Company
Velcro nylon hook and pile tape	Velcro Corp.
Adhesive backed Kapton Tape	Technical Fluorocarbons Eng., Inc.

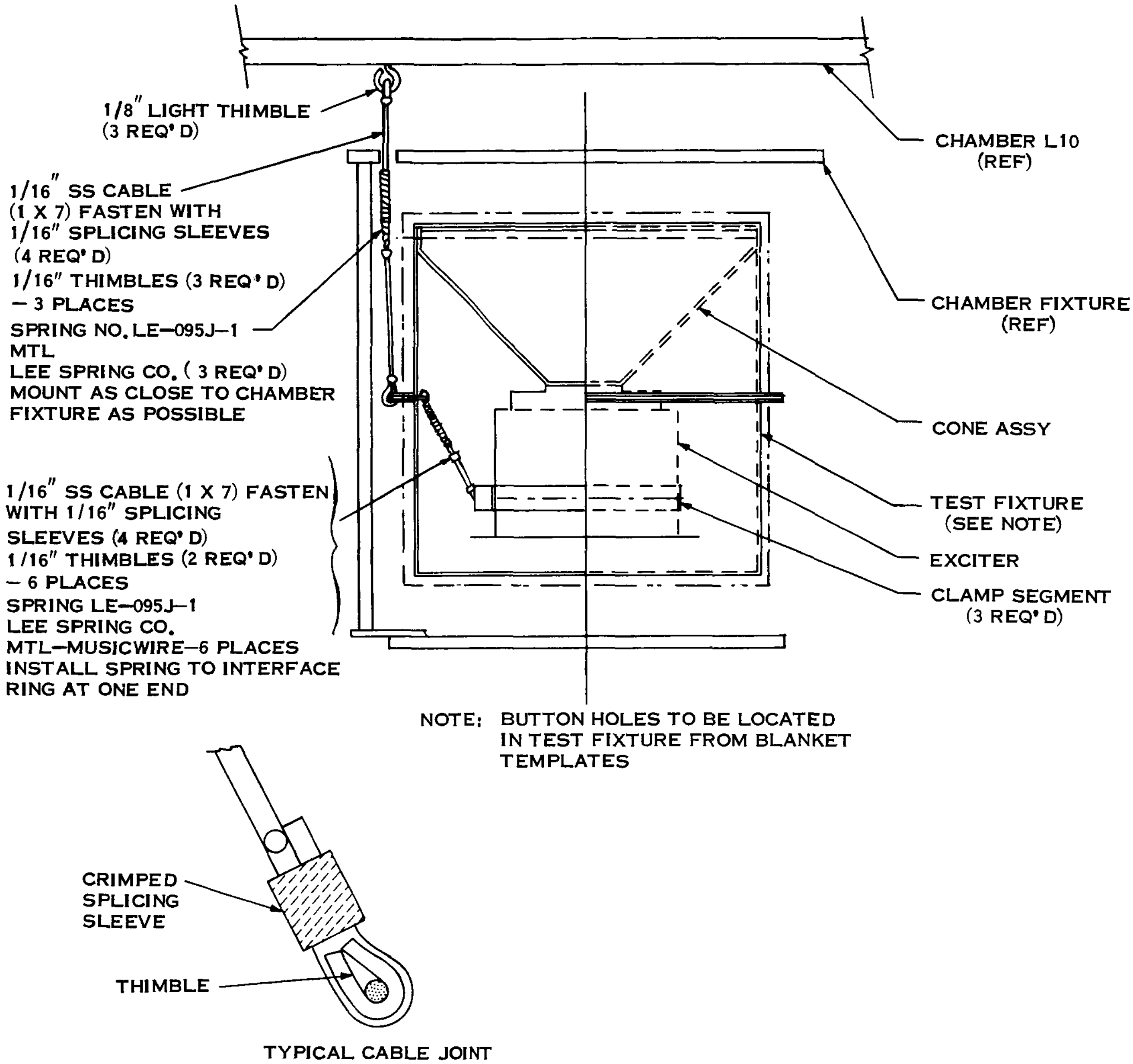


Figure 2-1. Long Term Thermal Vacuum Test Fixture

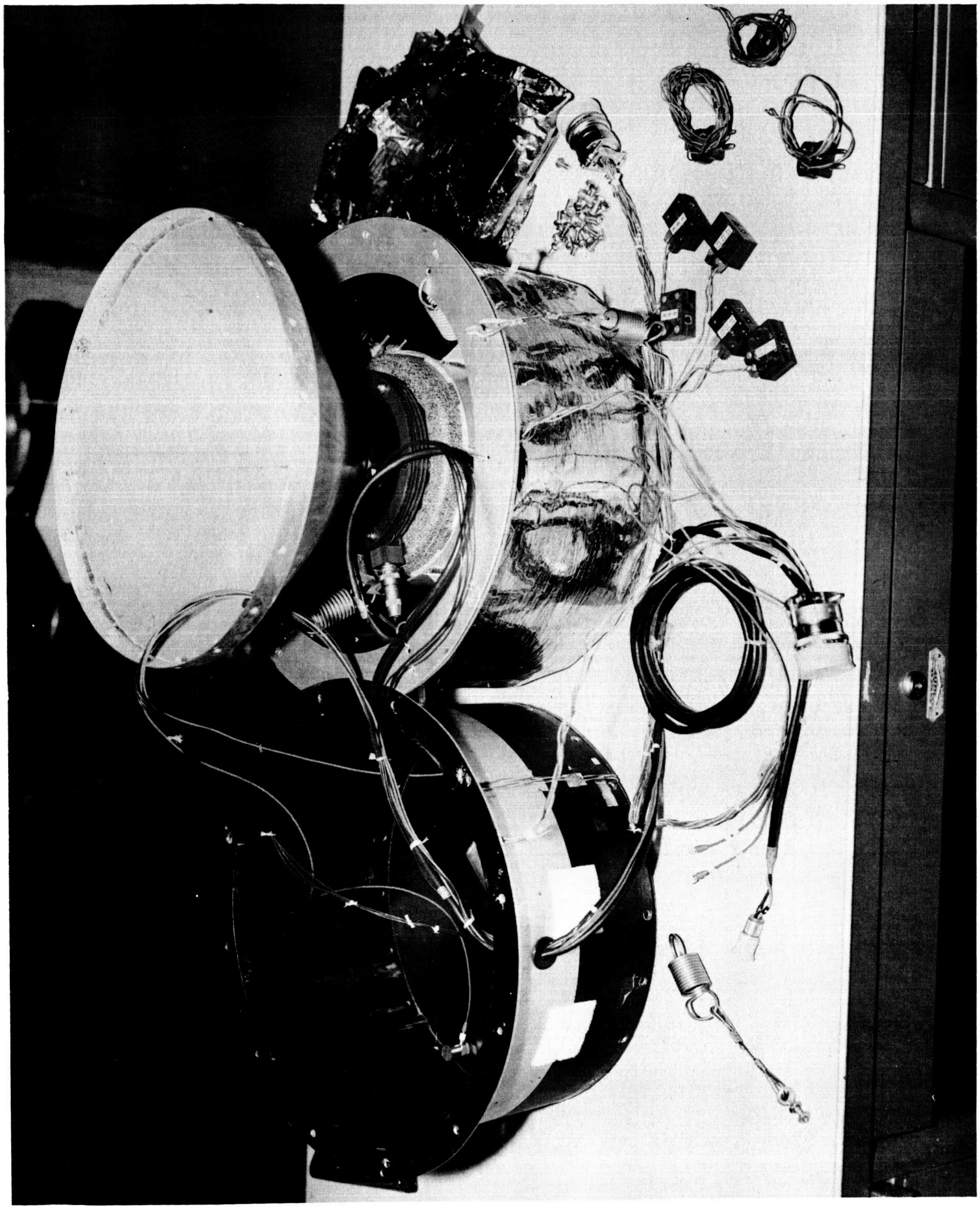
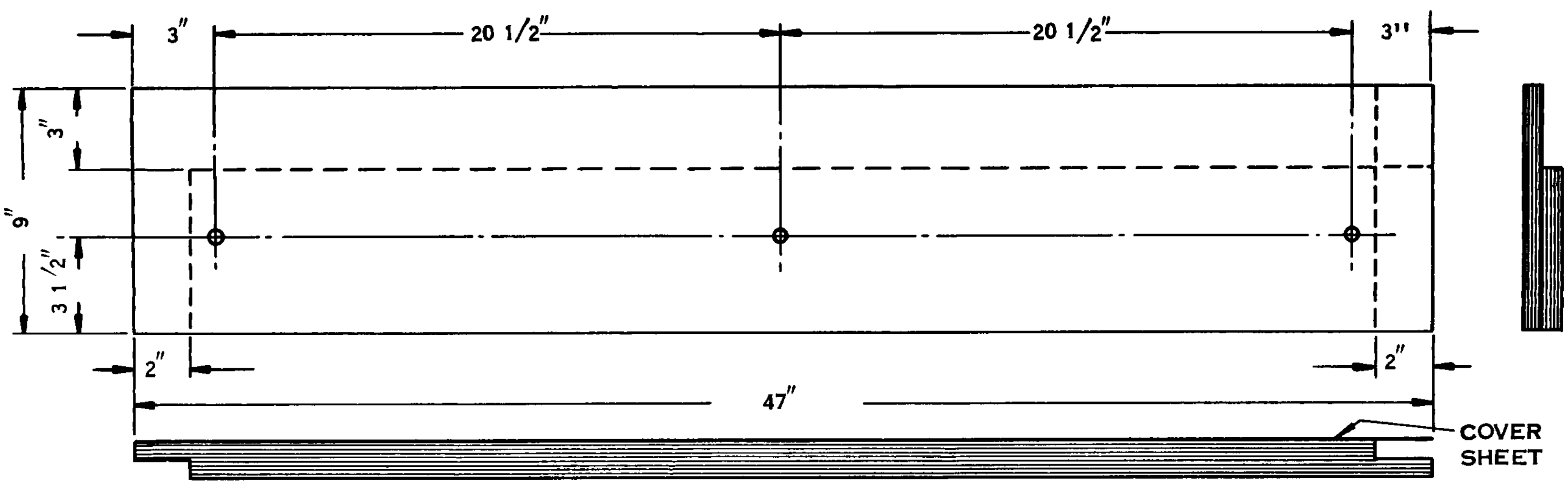


Figure 2-2. Dismantled Test Fixture



G1 { 19 LAYERS GOLD COATED 1/2 MIL KAPTON
1 LAYER COVER SHEET 2 MIL KAPTON

G2 { 19 LAYERS GOLD COATED 1/4 MIL MYLAR
1 LAYER COVER SHEET 2 MIL KAPTON

NOTES:

1. 1/2 MIL KAPTON AND 1/4 MIL MYLAR TO BE PERFORATED AND CRINKLED
2. 2 MIL KAPTON TO BE PERFORATED

Figure 2-3. Body Insulation Blanket

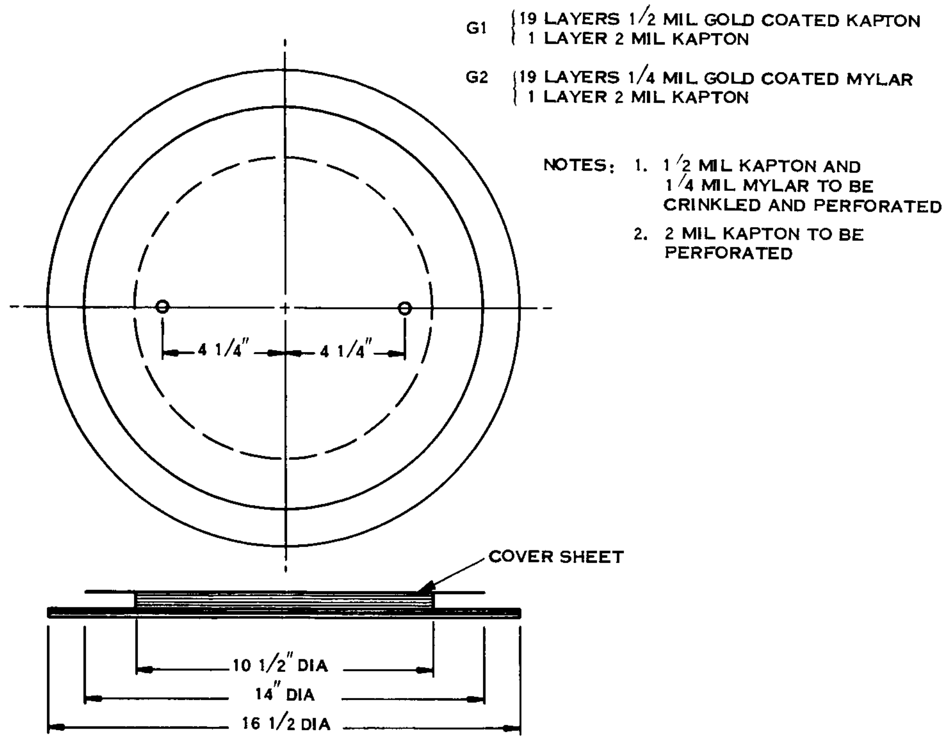
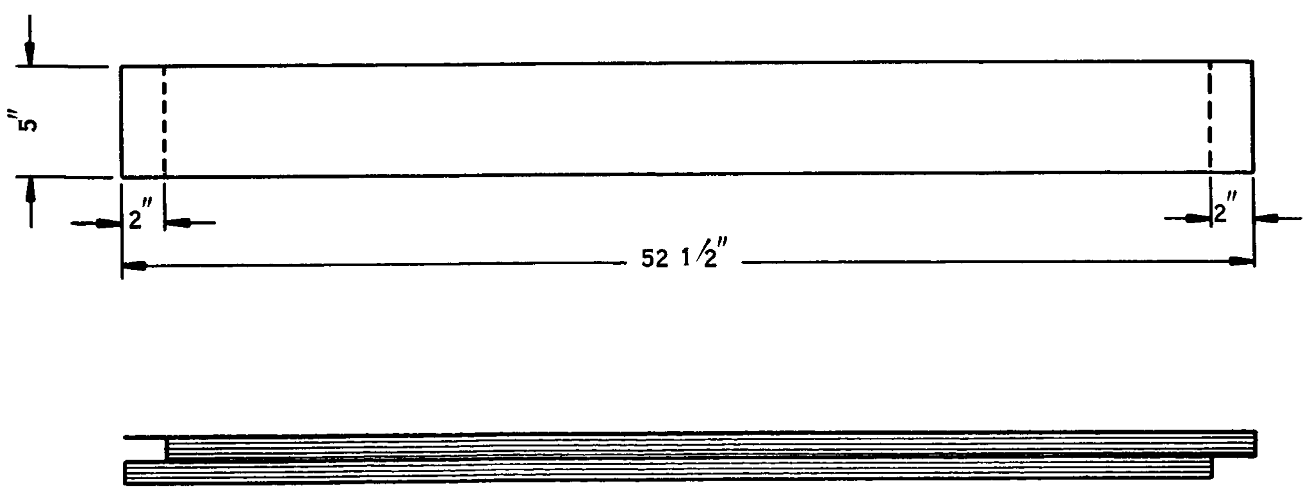


Figure 2-4. End Insulation Blanket



19 LAYERS 1/4 MIL GOLD COATED MYLAR--CRINKLED AND PERFORATED.
1 LAYER 2 MIL KAPTON--PERFORATED

Figure 2-5. Flange Insulation Blanket

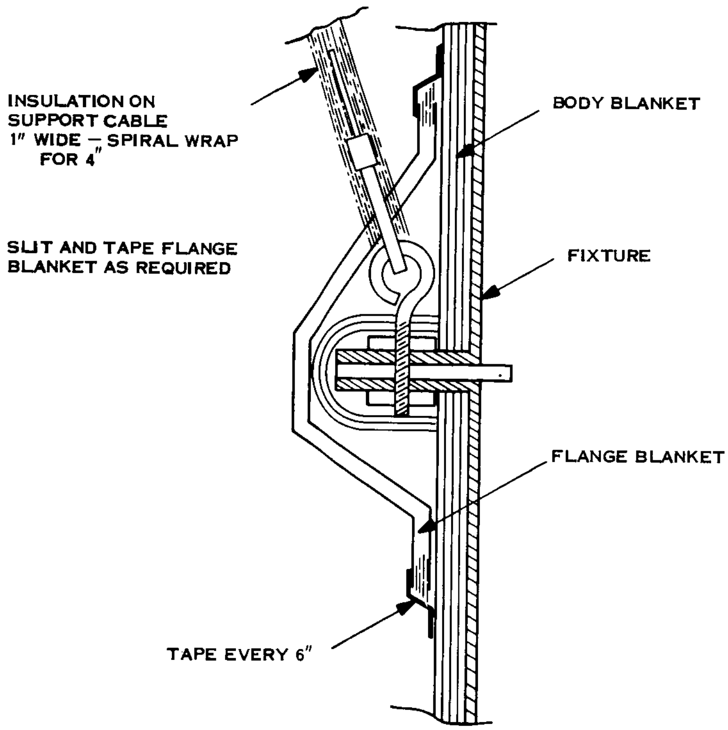


Figure 2-6. Flange Insulation Detail

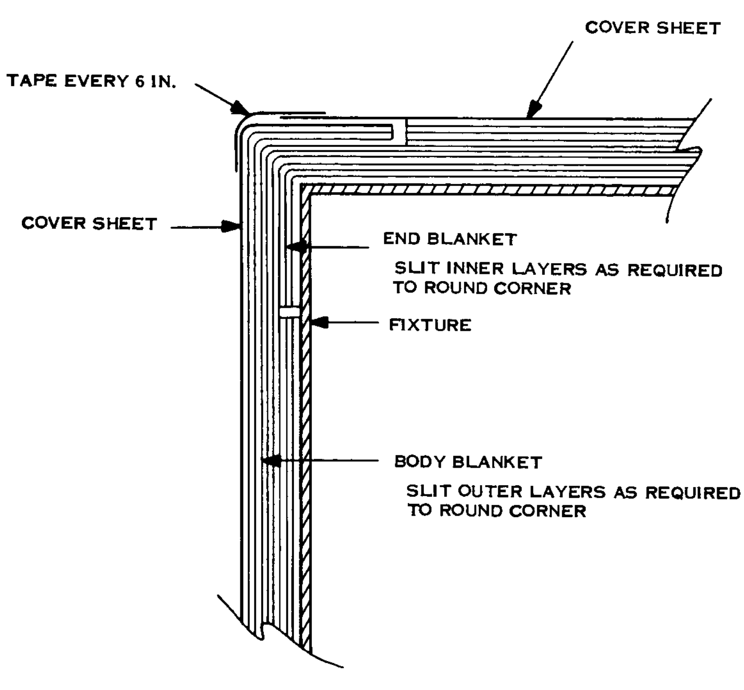


Figure 2-7. Corner Insulation Detail

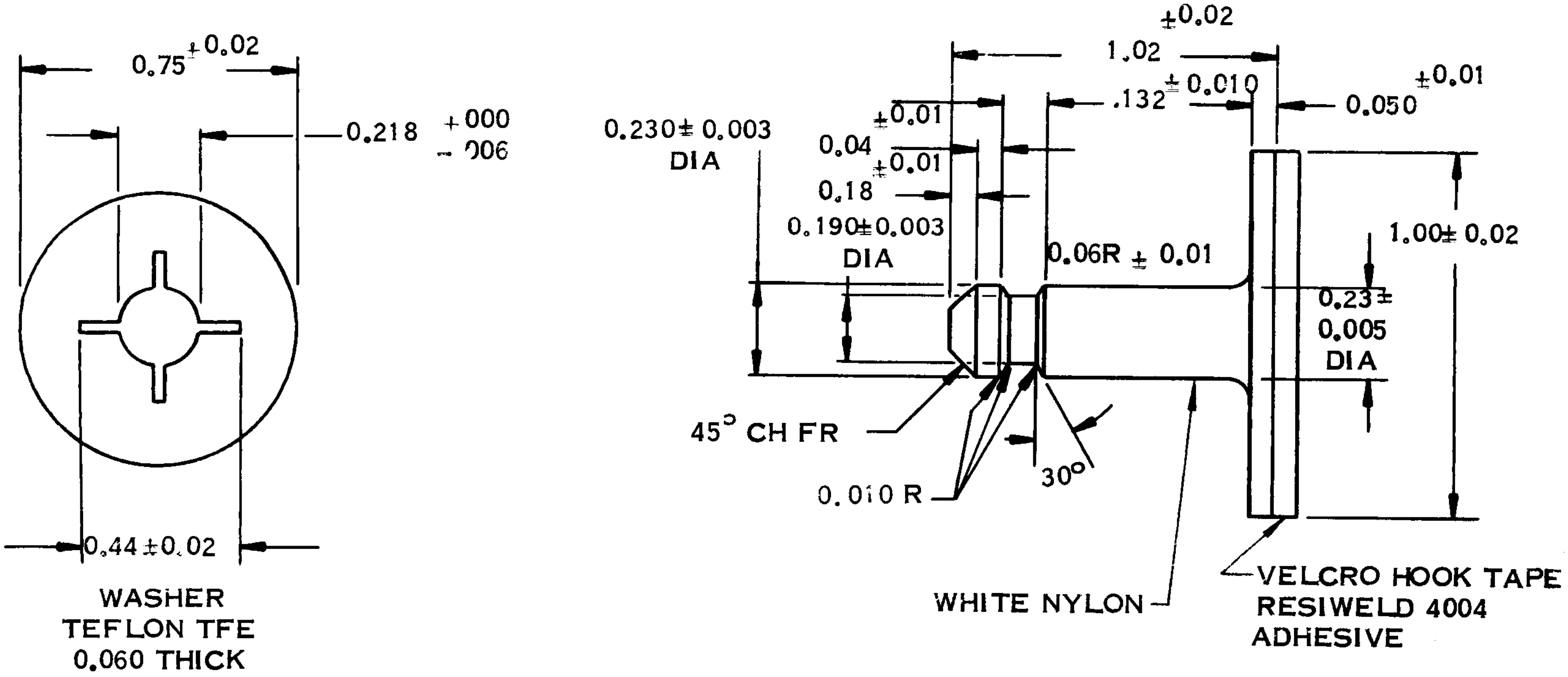


Figure 2-8. Tinger Fasteners

2.3 TEST FACILITY AND EQUIPMENT

The test was performed in a 2 ft by 2 ft thermal vacuum chamber located at the Valley Forge facility. Photographs of the test fixture and vibration exciter are shown in Figures 2-9 and 2-10.

2.4 TEST RESULTS

2.4.1 TEST CONDITIONS

The vacuum level throughout the test was maintained between 1.6×10^{-7} and 2.5×10^{-8} torr. Shroud temperatures were below $-280^{\circ}F$ during the test. A reference internal temperature of the test model was held between $+36^{\circ}F$ and $+51^{\circ}F$ with variations of $+10^{\circ}F$ to $-9^{\circ}F$ from the reference location. The total exposure to the test conditions was 1440 hours (60 days) before vibration excitation,plus four days for evaluation of thermal conductance change.

2.4.2 VIBRATION TEST

Prior to starting the vacuum test, the vibration spectrum was run under ambient pressure and temperature conditions to check out operation of the vibration set-up. The vibration levels simulated, as closely as possible, vibration levels measured in static tests of the LEMDE thrust chamber assembly. The total vibration time was three and one-half minutes. An inspection of the insulation system indicated no visible damage after the excitation.

At the conclusion of the sixty day thermal vacuum exposure, and with vacuum and temperature conditions maintained, the model was again subjected to vibration. Figures 2-11 and 2-12 depict the power spectral density for the control accelerometer and accelerometer No. 2, respectively. Two accelerometers were used for redundancy purposes, in case of failure of one of the units. The frequency spectrums were essentially unchanged from the values recorded prior to the start of the vacuum exposure cycle. As may be seen from Figure 2-11, the overall vibration spectrum showed reasonable correlation with the specified levels. Several peaks at 160, 460, 550, 650, 730, and 840 cycles are considerably above the

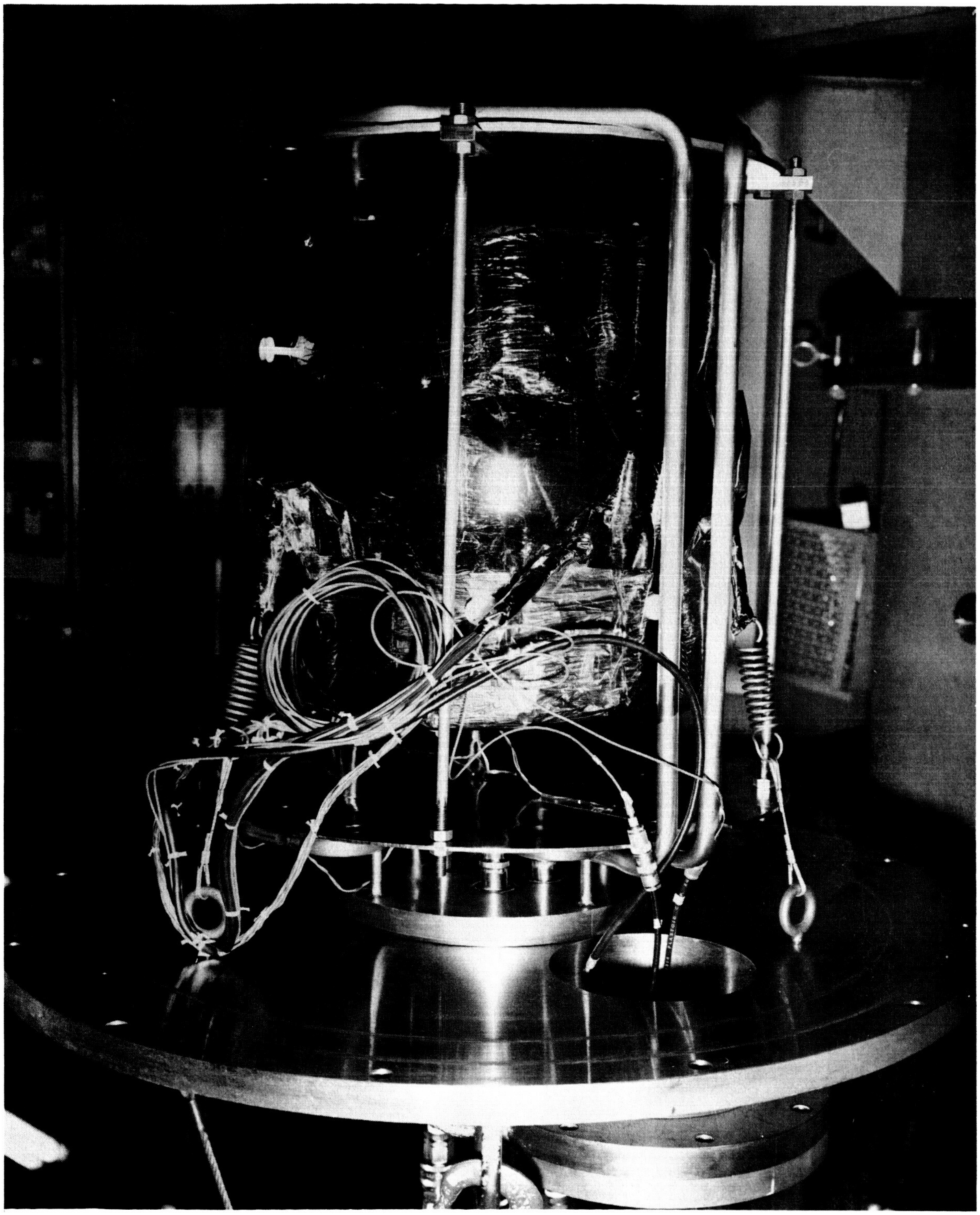


Figure 2-9. Assembled Insulated Test Fixture

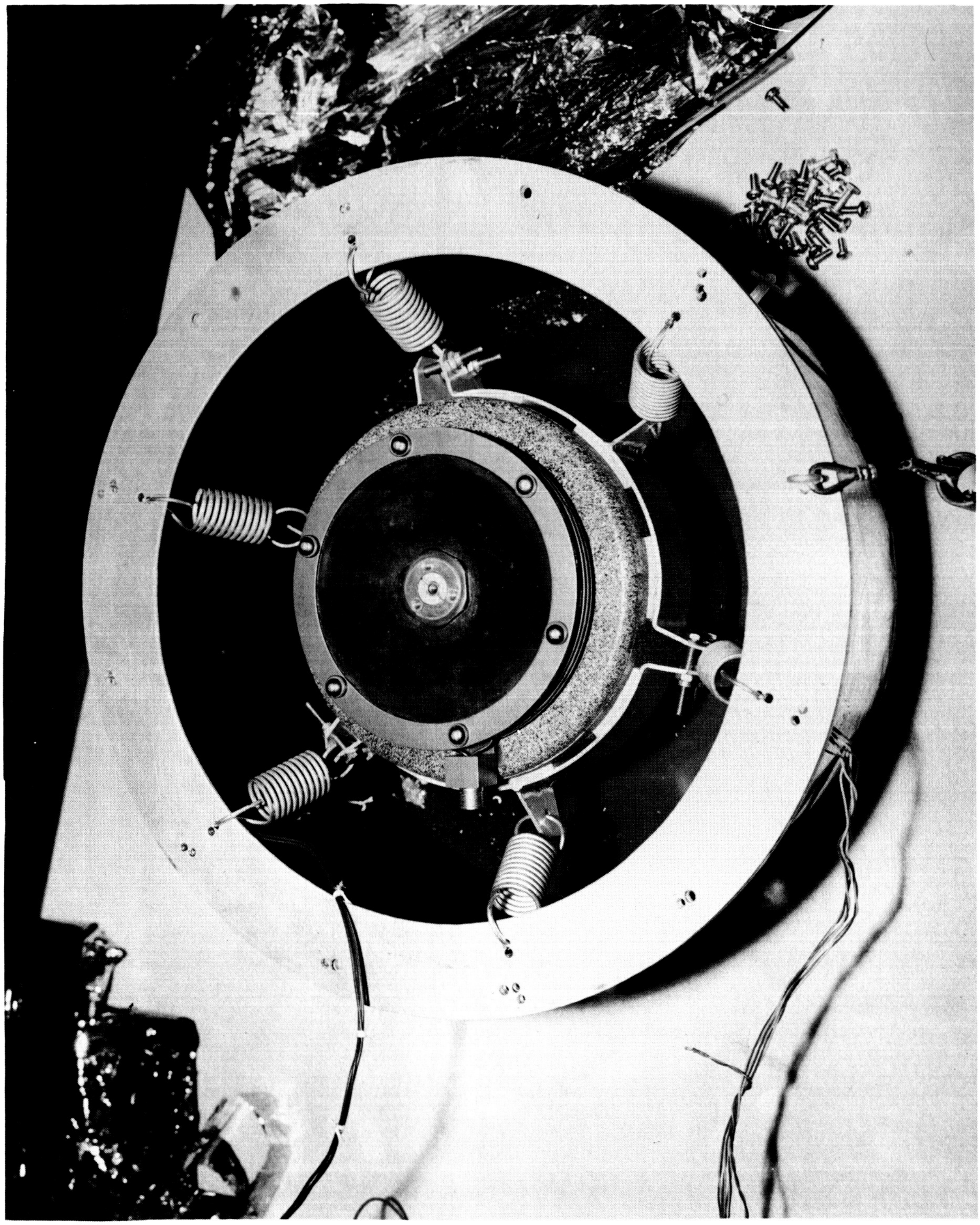


Figure 2-10. Exciter Mounting

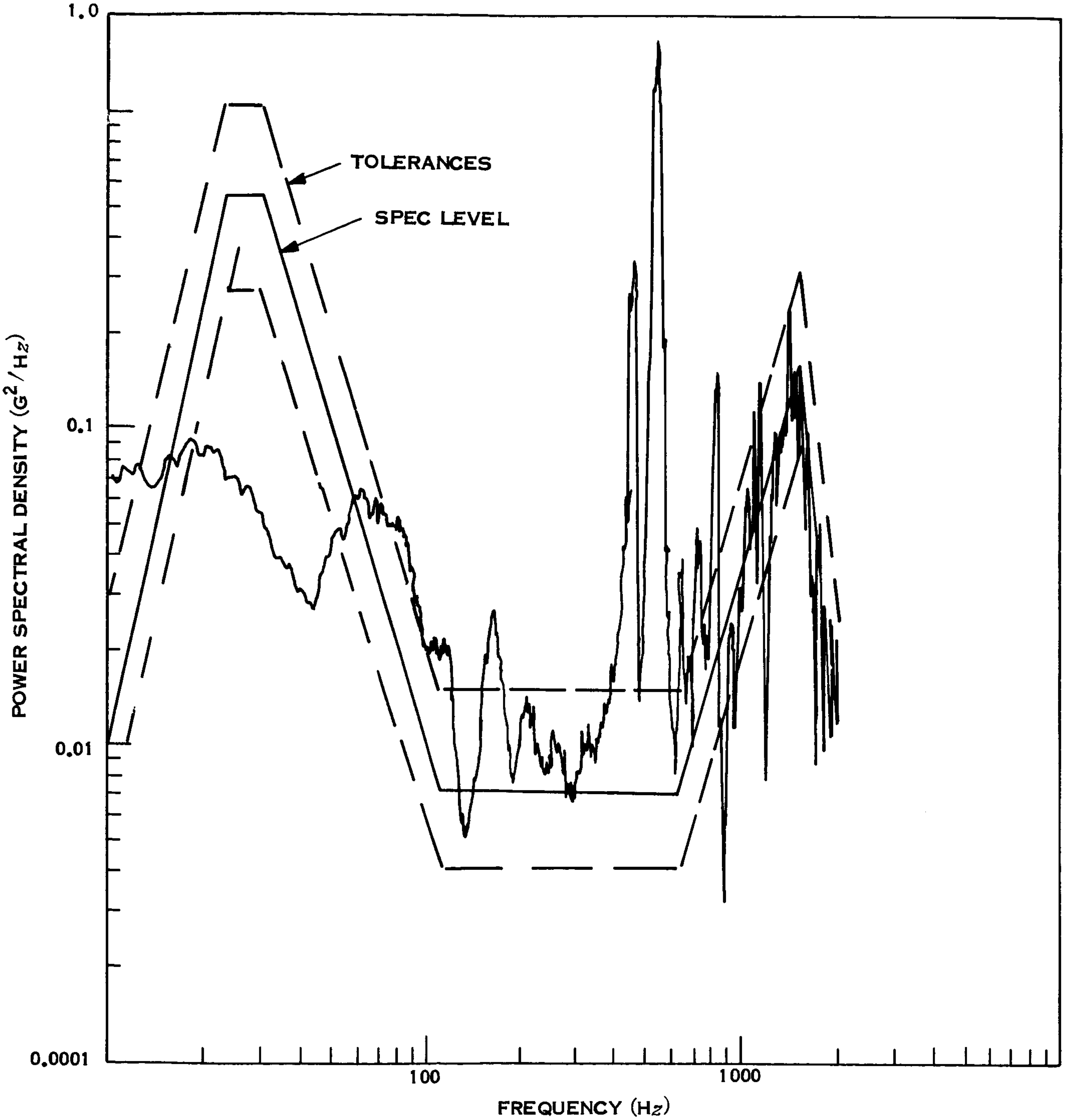


Figure 2-11. Power Spectral Density-Control Accelerometer

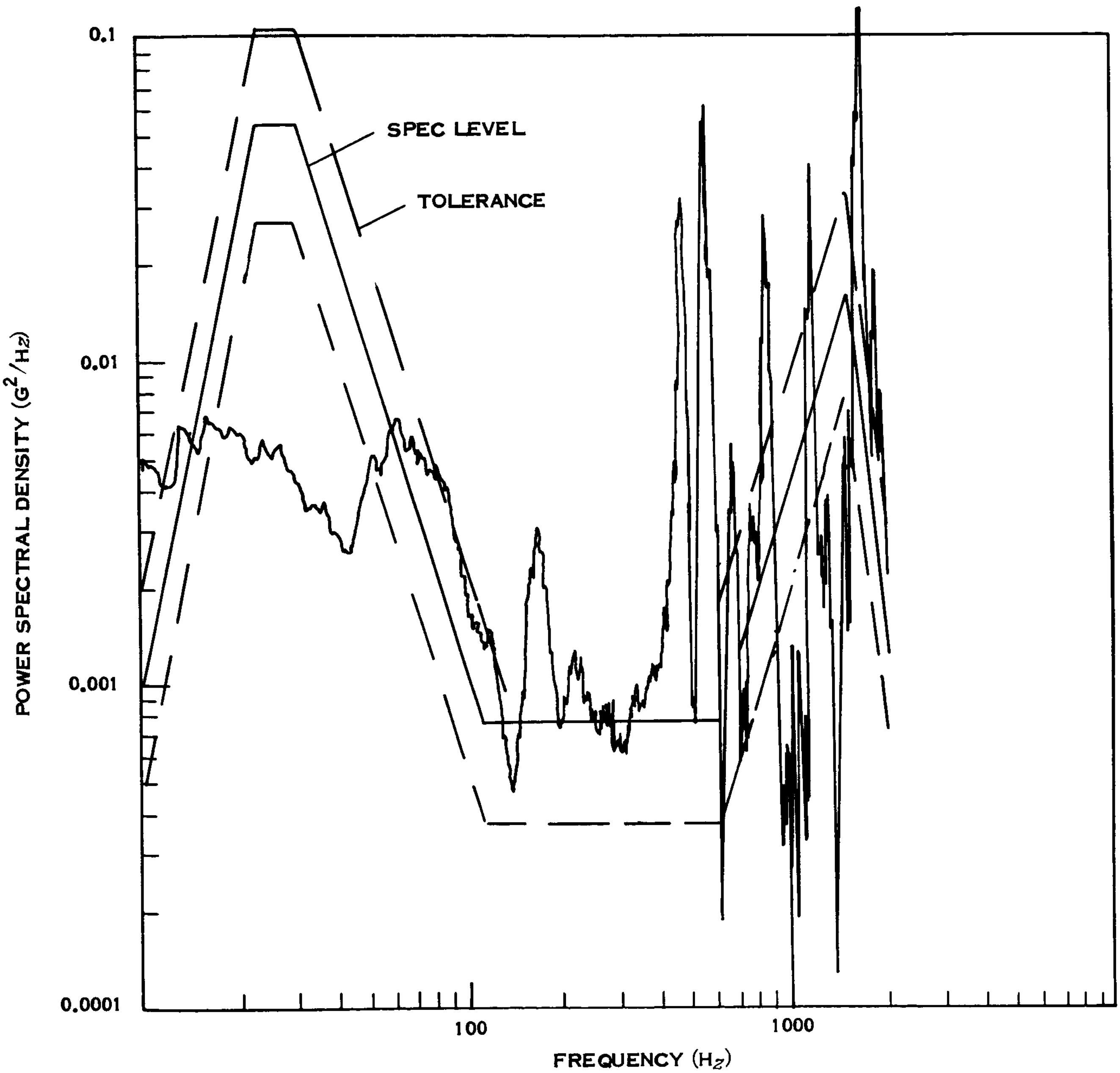


Figure 2-12. Power Spectral Density-Accelerometer No. 2

specification levels and peaks at 900, 960, 1700, and 1800 cycles are below specification levels. These correspond to resonances in the test fixture, which were confirmed by a plot of acceleration/exciter voltage versus frequency.

Total vibration time for the vacuum vibration test was five minutes and 18 seconds, with 120 seconds at the specified test levels.

2.4.3 INSULATION THERMAL PERFORMANCE

The long term vacuum test provided an opportunity to obtain data on the effectiveness of the multilayer insulation design proposed for the full scale tests. The performance of the insulation on the 14-inch long cylinder should be appreciably worse than that applied to the full scale fixtures because of the increased length of joint seams and increased number of support posts per unit area on the smaller model. In addition, the support cables and electrical lead wires will cause a greater proportionate thermal leakage in the small model than will similar disturbances in the full scale test.

During test with liquid nitrogen-cooled chamber walls, 3.7 watts power was required to maintain the model at about $40^{\circ}F$. At this condition, thermocouples mounted on the cylinder ends adjacent to the heaters read about $45^{\circ}F$, and thermocouples near the central parting flange were about $35^{\circ}F$. The 3.7 watts power value is an average over one day's time, with the actual values up to 0.2 watts above that at night and about the same amount below during the day due to plant line voltage fluctuation.

The lead wire bundle included six 24-gage copper-constantan thermocouple lead wire pairs, six 20-gage copper heater power wires, two accelerometer coaxial cables, and the shaker power cable. This bundle was wrapped with insulation to about 5 inches from the model, and included a thermocouple 2.5 inches from the model. The couple read about $-65^{\circ}F$ during test. Calculations show that at least 0.5 watts could leak through this bundle at these conditions.

The model was supported by three 1/16-in. diameter steel cables. Thimbles were used at each eyebolt in the model flange. The cables and thimbles penetrated the "belly band" of insulation used to cover the flange area of the model. There is no readily available data on the thermal loss through this type of insulation penetration, but is estimated that the leak is probably as much as 0.7 watts total for the three cables. Thus, the heat loss directly through the insulation is estimated to be 2.5 watts (3.7 - 0.5 - 0.7).

Including both sides of the one-inch wide central flange, the model has 7.08 square feet of surface area. This gives a heat loss of about 0.35 watts per square foot. If the heat loss were that much from the 472 square foot full scale capsule fixture, it would result in 165 watts loss. This is higher than the calculated capsule loss of 106 watts at 40°F, but it would be within the values specified by JPL as design requirements for the program.

Data was taken after completion of the vibration cycle and no measurable change in thermal performance was noted.

SECTION 3

CONCLUSIONS

The results of the vacuum/vibration test have led to the following conclusions:

a. The insulation material, Velcro mounting pad material, tingers, and tape exhibited no noticeable damage or change in physical appearance or function after exposure to vacuum and vibration.

b. The insulation system as installed on the fixture exhibited no measurable change in thermal performance after exposure to the vibration.

SECTION 4
RECOMMENDATIONS

It is recommended that this test be considered a materials qualification test for the ability of the materials listed in Section 2.2 to withstand the vacuum and thermal environments encountered during the planetary transfer orbit followed by the vibration levels expected from the firing of the orbit insertion rocket engine.

SECTION 5

NEW TECHNOLOGY

No reportable items of new technology are deemed to have resulted from the effort reported herein.